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Monitoring and Evaluation of a Point-of-Use Water Treatment Pilot Project in the Peruvian Amazon

Lia Brune, Ahn Lee, Johnny Moreno, Camila Restrepo, Elizabeth Travis

Research Advisor: Jami Nunez
Faculty Advisor: Karl Linden

Project Partners:
Universidad Nacional de la Amazonía Peruana (UNAP)
Bernuy Zumaeta Marcelo
Cleydi Paredes Meneses
Reynaldo Javier Minaya Vela
Carlos Andrés Medina López
Helita Del Carmen Cardenas Goncalvez
Moniika Stheefanny Paredes
Carmen Valeria Vela Hernández
Gober Maytahuari Aricari

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Introduction

Project History

The Civil Association for the Conservation of the Peruvian Amazon Environment (CONAPAC) is a non-governmental organization (NGO) that promotes education and clean drinking water in communities along the Amazon and Napo rivers in Peru. CONAPAC has partnered with students and faculty at the University of Colorado (CU) Boulder to conduct monitoring and evaluation of water treatment plants and point of use water treatment systems implemented in these areas. The collaboration has been facilitated by a National Science Foundation (NSF) – International Research for Students (IRES) grant (IRES: Toward Sustainable Water and Sanitation Infrastructure National Science Foundation OISE – 1065050; Karl Linden, PI). The project is in its third year of annual monitoring and evaluation.

The 2013 IRES team consisted of students from the University of Colorado and the National University of the Peruvian Amazon (UNAP). The collaboration meets the goal of the IRES grant to bringing together students from interdisciplinary backgrounds to achieve a comprehensive level of research in sustainability. The group from CU is comprised of four graduate students and two undergraduate students in the diverse fields of environmental engineering, political science, geography and environmental science. Water treatment systems were evaluated not only from a technical standpoint but for political and sociological factors as well. The technological, sociological, and economic factors of a project are fundamental to resilience and sustainability, highlighting the importance of a multifaceted approach to the IRES research.

CONAPAC is currently piloting a point-of-use (POU) water treatment system that incorporates a Sawyer membrane filter in three communities located on the Amazon and Napo rivers: 28 de Octubre, 7 de Julio, and Nuevo San Juan de las Amazonas. The small population and distance between the homes of these communities has made the installation of water treatment plants an inefficient solution. As a result, these communities were selected for a pilot project to test the effectiveness of POU treatment systems in the area. Through this pilot project CONAPAC aims to discern whether implementation of the POU system in similar communities as the primary form of drinking water treatment is feasible. Furthermore, the long-term goal is to expand the use of the POU system by making it an auxiliary option for communities whose access to water treatment plants is affected by annual flooding.

Of the three communities selected, the households that agreed to participate in the study were given the POU system at no cost and were required to sign a contract stating that the study period was six months and after that time the households could purchase the system for 50 soles if they would like, otherwise the system would be collected by CONAPAC. The contract also stipulated participation in household visits by the CU research team. All of the households that were present

during the CONAPAC solicitation visit to their community agreed to participate in the study, a total of 61 households.

The POU systems were installed during April and May of 2013. Households were provided verbal instruction of proper water treatment during installation of the POU system and a laminated instruction sheet on proper configuration and backwash was distributed with the systems. The CU research team visited the communities approximately three months after installation of the POU systems.

Water Treatment System

The CONAPAC POU System is a three-step water treatment process consisting of three plastic 20-liter buckets and a Sawyer PointONE Filter, which uses hollow-fiber membranes (Figure 1). The Sawyer component of the POU system consists of the membrane filter and hose, a syringe for backwashing, a carving utensil for connecting the filter to a bucket, and a hanging device in order to hang the filter from a bucket. The filter is designed to achieve 0.1-micron filtration at all times, resulting in 99.99% removal of bacteria, protozoa, and cysts (Sawyer, 2013a).

Figure 1. Sawyer PointONE™ hollow-fiber membrane filter kit

Figure 2 shows the 3-bucket POU system installed in a household. Raw water is collected from a river or stream using the first bucket. Raw river water turbidity has been found to range between 70 to 150 nephelometric turbidity units (NTUs), based on findings from previous visits by CU students.

Users are instructed to swirl a solid aluminum chloride crystal, which is sold in the nearby city of Iquitos, for 60 seconds in the first bucket to allow for coagulation to occur. The aluminum chloride binds with the natural organic matter present in the raw water and settles to the bottom of the bucket. This step in the treatment process was added by CONAPAC to increase the efficiency and lifespan of the Sawyer filter by removing the suspended solids before they pass through the filter. The water from the first bucket is then manually poured into the second bucket. Care must be taken to keep the suspended solids that have settled in the first bucket from becoming reentrained and entering the second bucket. The last step of the filtration process is the passing of the water from the second bucket through the Sawyer filter and into the third bucket. The filter is connected to the side of the second bucket through a connector valve located near the bottom. Water is gravity fed through the filter and is passed into the top of the uncovered third bucket through a small hose. The third bucket serves to store treated water, and has a collection tap to prevent

recontamination that can occur by dipping utensils into the bucket itself. Users are instructed to backwash the filter as needed by using a 60 mL syringe to pass treated water through the filter three times in the reverse direction of water flow during treatment. Sawyer advertises that when consistently backwashed the filter has an average flow rate of 46.6 liters per hour at sea level with a pressure head of 35.60 cm to 66.00 cm (Sawyer, 2013b).

Figure 2. CONAPAC point-of-use water treatment system installed in a household

Sampling Methodology

The IRES team evaluated the use, sustainability, and effectiveness of the POU system through household surveys and water quality testing. The survey looked at the use and sustainability of the system while the water quality tests were used to identify fecal contamination at different points within the system.

Household Surveys

The research team attempted to survey every household in communities that received a POU system. Each of the three POU communities is relatively small, allowing for a complete and thus more representative assessment of the POU system. According to the data CONAPAC provided, there are a total of 61 households in the three communities with POU systems: 25 in 28 de Octubre, 15 in 7 de Julio, and 21 in Nuevo San Juan de las Amazonas. Out of 53 surveyed households, 49 had a POU system. Each survey lasted approximately 25 minutes. Initially the surveyor informed the interviewee, a member of the household; of the purpose of the survey and that his or her participation was completely voluntary and anonymous. If the interviewee gave consent and was 18 years or older the surveyor would proceed. Survey questions covered research areas such as water use, consumption rates, water treatment, storage, satisfaction,

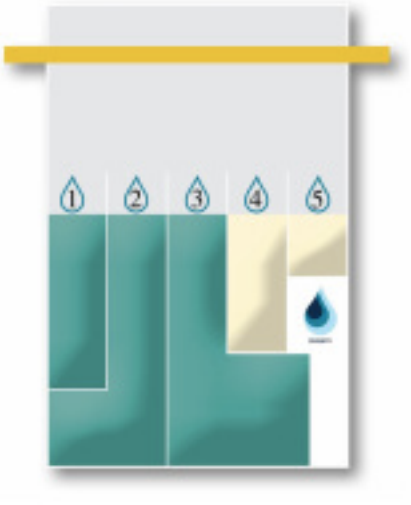

Figure 3. Schematic of the Aquagenx Compartment Bag Test

community cohesion, and demographics. The survey also included observation questions for the interviewer about the appearance of the POU system.

Water Quality

The Aquagenx Compartment Bag Test (CBT) was used to assess the presence and concentration of *E. coli*, an indicator organism for fecal contamination. The CBT consists of a bag with five compartments of varying volumes, with a total volume of 100 mL (Figure 3). The presence or absence of *E. coli* in each compartment is used to determine the probability that *E. coli* is present in the water sample and provides the most probable number (MPN). The CBT method was selected for microbial sampling in the field because it does not require refrigeration, is compact and light, and provides a most probable number.

As shown in Figure 4, samples were collected at three points within the POU system. The first sample site, labeled 2 in Figure 4, was collected from the second bucket after coagulation. Results from this point provided information about the *E. coli* concentration present in the water prior to its passage through the filter. The second sample site was taken directly after the water had passed through the Sawyer filter at sample site 2.5. Results from this sample site indicate whether or not the Sawyer filter is effectively removing bacteria. The third sample site was collected at the tap of the third bucket and was labeled sample site 3. Results from this point demonstrated whether or not recontamination had occurred in the third bucket during the storage period. Duplicate and sometimes triplicate samples were collected at the various sample sites to ensure quality control.

Figure 4. CONAPAC point-of-use system sample sites

Turbidity, the degree to which light traveling through a water column is scattered by the suspended solids, was measured in some of the households using a HACH 2100P field turbidimeter. The lower the turbidity the clearer the water appears. The HACH 2100P has a detection limit of 0.01 NTU. The turbidimeter was calibrated immediately before use to ensure accurate results. Turbidity was measured at sample site 2 in order to quantify the typical turbidity that passes through the filter and at sample site 2.5 in order to measure how much turbidity is being removed by the filter.

When the flow rate coming out of the Sawyer® filter was too slow to collect a 100 mL sample for the CBT, 3M™ Petrifilm *E. coli*/Total Coliform count plates were used. Total coliforms are another indicator of fecal contamination. A syringe was used to collect 1 mL of water from a sterile sample bottle with water directly from the filter. The 1 mL sample was placed on the Petrifilm containing a growth medium for coliforms. Samples were incubated for 48 hours and results were quantified as coliform forming units (CFUs) (3M, 2013).

Survey Findings

Survey results are presented in the following sections based on the research areas of water use, treatment, maintenance, system condition, and satisfaction. A total of 53 households of the reported 61 households that are in the three communities studied, were surveyed. Of the four households visited that did not own a POU system, two households reported that they were simply not home when the systems were distributed. Note that Tables in this section report responses of 101 and 102 suggesting the user responded "do not know" or did not respond to the survey question, respectively.

Use

All of the households with a POU system reported that the systems were currently functioning and **the vast majority of respondents described the system as either "very easy" or "easy" to use.** Four percent described the system as "not easy" and two percent described the filter as "difficult" to use.

Table 1 shows what households reported when asked how often they treat water in a normal week using the POU system. The large number of households that are treating water less than every other day suggests that **users are storing water for multiple days, thus increasing the likelihood of contaminating treated drinking water**. Due to the lack of a residual disinfectant in the treated water, there is no barrier against microbes that enter the third storage bucket due to improper handling, i.e. dipping a utensil or hand in the bucket or leaving the bucket uncovered.

Table 1. Frequency of household water treatment per week

Treatment per week	1	2	3	4	7	14	21
Response frequency	8	11	10	2	16	1	1

Treatment

Only 1 household out of 43 reported that the system does *not* always work. The household's explanation for the system's malfunction was a lack of alum for coagulation rather than a problem with the POU system filter. Table 2 displays the variation in the amount of time users spent mixing the coagulant in the first bucket. During the distribution and installation of the POU systems, CONAPAC

recommended that users swirl alum for 60 seconds in the first bucket. However, lab tests conducted at CU Boulder have shown that a minimum of 120 seconds of swirling is necessary in order to settle out the maximum amount of turbidity. A majority of households reported swirling water for only 30 seconds, suggesting that they either never received a recommendation for how long to swirl the alum or are swirling for less time in order to conserve the alum. **There is a lack of understanding of the appropriate amount of time to swirl alum, most likely leading to less than optimal coagulation and settling.** Thus resulting in higher turbidity passing through the filter, which can lead to lower flow rates passing through the filter and possible clogging.

Table 2. Amount of time users swirl the coagulant in the first bucket

Swirling time (in seconds)	2	30	32	60	101
Response frequency	1	29	1	17	1

Reported settling times were also found to vary between households. As Table 3 shows, the majority of households reported allowing 30 minutes for settling in the first bucket before pouring water into the second bucket. Lab test results conducted at CU Boulder found that a settling time of 40 minutes is ideal. **The lack of consistency among respondents indicates that an optimal settling time has not been effectively communicated to users.**

Table 3. Settling time in the first bucket

Settling time (minutes)	5	15	20	30	45	50	60	101	102
Percent of total responses	4	2	2	69	2	2	13	4	2

Maintenance

Out of the 49 households surveyed, 48 acknowledged that they occasionally needed to clean the filter and most reported the need to clean it after every use. Table 4 shows the little variation in the frequency with which households reported backwashing their filter. Overall**, users seemed to understand the need to backwash the filters and the majority backwash every time they treat water**. This is largely attributed to the total inability to treat water, i.e. no water passing through the filter, without backwashing after every bucket of water treated. It should be noted that the flow rates advertised by Sawyer are based on testing that used recreational waters that have naturally low turbidities, which is in stark contrast with the water sources being used in these communities. Based on the few number of households where turbidity was measured, the average turbidity of water before passing through the Sawyer filter was found to be 10 NTUs. Large variation in the turbidity of the water passing through the filter is expected due to the large variation in water treatment methods used in households.

Table 4. Frequency of filter backwash

Number of buckets treated before backwash	1	2	3	4	101
Frequency of response	29	12	3	3	2

Table 5 shows variation in the number of times households backwashed the filter using the syringe provided with the POU system. The variation in these responses suggests two possibilities, though not mutually exclusive; **1) knowledge regarding maintenance requirements varies widely between households; 2) maintenance guidelines that suggest flushing three 60 mL syringes of treatment water through the filter are insufficient.** It should be noted that users do not have a user manual to reference for information on proper backwashing. Lab tests conducted at CU Boulder found that flow rates through the filter during water treatment improved when backwashed with a syringe six to nine times.

Table 5. Number of syringes used to backwash filter

Number of syringes	1	2	3	4	5	6	8	10	15	101
Frequency of response	6	3	12	6	5	4	1	3	3	5

System Condition

In regards to the condition of the systems, surveyors found that approximately 35 percent were in "perfect" or "near perfect" condition, 58 percent were in "good" condition, and 5 percent were in "poor" condition. One POU system was reported to not be in use. Only one of the 39 systems was reported to have a leak (Figure 5), and the user of the system had attempted to plug the leak using a plastic bag. A total of 18 percent of the 49 systems were missing a lid on the third bucket at the time of the visit, while the collection tap in the third bucket was not functioning in 10 percent of the POU systems. A total of 11 out of 49 households reported that they did not have alum. Six of these households were in Nuevo San Juan de las Amazonas, where CONAPAC arranged for surveyors to distribute alum during their visit. It is important to note that some households in Nuevo San Juan de las Amazonas responded that they did have alum because they had received it on the day of the survey. Thus, the data may not reflect the situation as it was prior to the survey. **Aside from not having alum, the systems were generally in good condition.** It should be noted though that the visit occurred only three months after the systems had been installed, thus a follow up survey conducted at a later date would provide a more accurate representation of how the system

Figure 5 A leak in the Sawyer filter tubing.

will perform in the harsh Amazon environment over time.

Satisfaction

Most households, 55 percent, reported high filter flow rates, while 35 percent reported slow flow rates, and 6 percent reported that flow rates were too slow. When asked if after six months they would be willing to purchase the system 96 percent of households responded "yes."

Table 6 shows the amount of money respondents stated they would be willing to pay per month for the POU system, if this was an option that CONAPAC offered. While most households demonstrated a willingness to purchase the system with one payment of 50 soles, these findings suggest a preference to pay in monthly increments. The most common incremental value was 10 soles per month.

Table 6. Desired monthly payment for POU system

Willingness to pay per month	1	3	5	15	20	25	50	100	101
Frequency of response	1	1	7	10	1	4	3	8	1

Water Quality

Turbidity

The CONAPAC POU system removes turbidity primarily through the use of alum in a coagulation process and secondly through the Sawyer membrane filter. The removal of turbidity was between 86 and 98.8 percent in the six filters whose turbidity was measured in the field both before and after treatment. According to the World Health Organization (WHO) the maximum allowable turbidity in drinking water is below 5 NTU, with a preferable measure of below 1 NTU to ensure that chlorination will be effective if in use (Adams, 2009). Turbidity measurements following treatment with the Sawyer filter were collected in 12 different households. Final turbidity readings after the filter ranged between 0.27 and 1.66 NTUs, with only two samples reading above 1 NTU. The average NTU for the third or final bucket was 0.65 NTU. While turbidity was only tested after filtration in 12 households, **the results indicate that between coagulation with alum and the Sawyer filter, turbidity is being removed to a level that meets WHO standards**. An important corollary of this finding is that a 1.1 log reduction in *E. coli* concentration due to coagulation using the alum crystal in the first bucket has been shown in investigations into the effectiveness of the POU system conducted at CU Boulder. This emphasizes the importance of removing turbidity for improving water quality and reducing the presence of pathogens. It should be noted though that the coagulation process with alum needs to be improved in order to put less stress on the Sawyer filter, and thus improve flow rates through the filter and overall lifespan.

Fecal Contamination

The water quality results of POU system pilot study are discussed below for each of the three communities separately before analyzing the results as a whole. While the goal of water quality testing of the POU system was to take water samples from sites 2, 2.5 and 3 from every household in each of the three communities, this was not possible in many cases. Barriers to taking samples at each site and in each household included leaking of the CBTs, availability of water to sample in both the second and third buckets, and the low flow rates from the filter at sample site 2.5.

28 de Octubre, July 23, 2013

Of the 23 households in the community of 28 de Octubre, 21 were surveyed (Table 7). Due to the complications previously explained, water samples were collected at a total of 15 households, 65 percent of the households in the community.

At sample site 2, in the second bucket, 73 percent of the households showed zero fecal contamination. As this sample site is prior to filtration through the Sawyer system but after coagulation, it was expected for some microbial contamination to remain. Possible explanations for these unexpected results are low initial contamination and removal via coagulation, inadequate incubation time due to lower than expected ambient temperatures, or inadvertent disinfection of samples due to prolonged exposure to the sun. It should be noted that the CBT tests only for *E. coli* and not other possible pathogens.

Table 4. Fecal contamination results from 28 de Octubre

	Sample site 2	Sample site 2.5	Sample site 3
Number of samples	15	12	15
% Positive for contamination	26.7%	16.7%	13.3%
% Negative for contamination	73.3%	83.3%	86.7%

Of the 12 samples collected directly from the filter at sample site 2.5, 17 percent, 2 samples, were found to be contaminated. Both of these contaminated samples tested negative for *E. coli* before passing through the filter. Possible explanations for this are that contamination occurred during the sampling process or that there is microbial growth within the filter itself.

Of the 15 samples collected at samples site 3, two samples tested positive for fecal contamination. Both of these positive samples were collected from Sawyer systems that tested negative for contamination at sample site 2.5, indicating recontamination in the third bucket. The two filters that tested positive for contamination at sample site 2.5 tested negative at sample site 3. Again, this could be due to mishandling during sample collection and analysis. Based on these results, **fecal contamination exists in the water being consumed and additional treatment should be added**

the POU system. A residual disinfectant, such as chlorine in the third bucket, would decrease the possibility for regrowth due to the chlorine residual allowing for continual disinfection during storage.

7 de Julio, July 26, 2013

Of the total 16 households in 7 de Julio, 81 percent were surveyed. Of these, water quality was tested in 75 percent of the households. At sample site 2, only seven households had water available to sample. Of these, 43 percent tested negative for contamination and 57 percent tested positive. Again, the lack of contamination in the second bucket in many households may be due to low amounts of initial contamination, variation in the coagulation and settling time, or sampling error.

Six POU systems were tested at sample site 2.5. Of these, three were tested using the CBT, while three were tested using Petrifilm. Three of these filters tested negative for contamination, while the other three tested positive, though at low levels. Where samples were taken at sample sites 2 and 2.5 for the same filter, the results were consistent with what was expected, if sample site 2 showed no contamination neither did sample site 2.5.

Samples were collected at sample site 3 in ten households. Four of these samples tested negative for fecal contamination. The other six samples tested positive. One sample had a MPN of greater than 100 *E. coli* per 100 ml, one sample had a MPN of 48.3 per 100 ml, and the other four samples had MPNs below 4.7.

Table 5. Fecal Contamination Results, 7 de Julio

	Sample site 2	Sample site 2.5	Sample site 3
Number of samples	7	6	10
% Positive for contamination	57.2%	50%	60%
% Negative for contamination	42.8%	50%	40%

Nuevo San Juan de las Amazonas, August 2, 2013

There are 21 households in the community of NSJ del Amazonas. Of these households, 81 percent were surveyed and 76 percent had their POU system tested for water quality. Most of the drinking water in this community is collected from large ponds. None of the households had alum before our visit.

Samples were collected from sample site 2 in five households and all of these samples tested positive for fecal contamination. Five samples were collected from sample site 2.5 and only one sample tested negative for contamination. Of the other four samples, two tested for low contamination with 1.5 and 2.5 MPN and the other two samples had MPNs of 48.3.

A total of 16 households had their water tested at sample site 3. Three tested negative for fecal contamination. Of the remaining samples, one had a MPN of 1.1, two had MPNs of 13.6, three had MPNs of 48.3, and seven had MPNs of greater than 100. The contamination of water in the third bucket can be attributed to improper storage of water, thus furthering the case for a chlorine residual in the third bucket to form a secondary barrier against microbial contamination.

It is unclear what caused such high levels of contamination in the treated water of NSJ del las Amazonas. Qualitative observations of household practices suggest an understanding of appropriate treatment procedures. It is possible that the frequent contamination is due to higher levels of fecal contamination in the source water, malfunctioning of the POU filters due to a lack of alum and higher turbidity levels, or microbial growth inside the filter.

Table 6. Fecal Contamination Results, Nuevo San Juan de las Amazonas

	Sample site 2	Sample site 2.5	Sample site 3
Number of samples	5	5	16
% Positive for contamination	100%	80%	81.2%
% Negative for contamination	0%	20%	18.8%

Cumulative Results

When looked at cumulatively (Table 9), **the water quality results indicate that the quality of drinking water is improved with the use of the POU system, but is not consistently providing water that is safe for consumption**. It is important to note that fewer samples were collected at sample sites 2 and 2.5 than at site 3. However, overall contamination levels at around 50 percent in the third bucket, whether due to failure of the system, sampler error, or recontamination, are an indication that **further action is needed to ensure that households are drinking clean water**.

Table 7. Fecal Contamination, all three communities

	Sample site 2	Sample site 2.5	Sample site 3
Number of samples	27	23	41
% Positive for contamination	48.1%	39.1%	51.2%
% Negative for contamination	51.9%	60.%	48.8%

Summary

Based on the water quality results, the POU surveys, and the impressions of the surveyors, these systems have the potential to provide clean drinking water to

users. The POU system is an attractive option for residents of small communities whose population or geographic layout makes the installation of centralized water treatment plants unfeasible. The use of alum for coagulation, when used correctly, has the potential to decrease turbidity levels to ranges around 10 NTUs. This is a major benefit as turbidity serves as a major conduit for pathogenic microorganisms. In addition to this benefit, the appearance of the final water offers an important pathway to making clean water consumption a symbol of social status.

Households that have the POU system showed an overwhelming willingness to pay for the system following the trial period. The households consistently asserted that they used the system. Interviewers noted that all but one system appeared to be in use while 93 percent of systems were in good or perfect condition. This indicates a commitment to improving drinking water quality and a willingness to take ownership for providing it.

Furthermore, we were able to observe the water treatment process in a number of households. Qualitative observations of household practices suggested an understanding of appropriate treatment procedures. If the system is adjusted so that recontamination is minimized through the use of chlorine and the optimum procedures for treatment are properly communicated, then residents appear capable of using the system effectively.

There are, however, a few caveats. As mentioned above, further action has to be taken to address fecal contamination in the final bucket. Adjusting the system so that the third bucket remains closed and adding chlorine should prevent recontamination and serve as a secondary barrier against microbial contamination. In addition, there needs to be better communication regarding the roles and responsibilities of community members and CONAPAC regarding system maintenance and also concerning optimal use of the system.

Recommendations

Our conclusions regarding the future feasibility of using the POU system hinge on improvements in communication between CONAPAC and recipient communities' as well additional refinements to the system aimed at improving water quality. Below are recommendations developed with both the shortcoming of the current setup and it's potential for transformative use in the future in mind.

User Manual

The existing manual that was included with the POU systems does not explain the full water treatment process. Thus, it is recommended that users be provided with a printed and laminated Spanish water treatment instruction manual for households to properly operate the POU system. Such a manual will reduce the common misconceptions and improper water treatment that was evidenced during household visits. Important instructions to include in the manual are as follows:

1) Swirl coagulant in first bucket for 120 seconds, or 120 swirls.
2) Allow water to settle for a minimum of 40 minutes.
3) After settling, transfer water into the second bucket, trying to prevent the settled particulate matter from becoming reentrained in the water during this transfer. Water will then flow through the Sawyer filter. The water should flow freely, without interruption.
4) The filter needs to be backwashed before each new bucket of water is treated, or more frequently if flow rate slows down significantly. During backwashing, treated water is passed through the filter using a 60 mL syringe in the reverse direction of water flow during treatment. Force should be applied to the syringe in order to flush out particulate matter inside the filter. A minimum of five syringes of treated water should be passed through the filter during backwash.
5) Add one to two drops of liquid chlorine to third bucket to attain free chlorine in the water. After chlorine addition, shake the bucket manually, with the lid closed in order to prevent spillage, in order to mix the chlorine. After mixing, let the bucket sit for approximately 30 minutes to allow time for the chlorine to disinfect the water.
6) Water from third bucket is now treated and ready to consume. Be especially careful not to insert hands or utensils into this bucket, as this increases the risk of recontamination. Instead, always use the tap to collect water.
7) Keep the third bucket covered at all times.
8) Should the filter malfunction, contact CONAPAC. Provide contact information. When alum is needed, it can be purchased in Iquitos. CONAPAC will not provide alum.

Chlorine addition in the 3rd bucket

One recommendation is that the system be augmented with the addition of chlorine in the third bucket. Storage time is an unknown variable and increasing storage time can lead to an increased chance for recontamination. Adding chlorine would help prevent recontamination and also serve as a secondary method of disinfection.

Increased Coagulation Time

Increase the amount of time the user stirs the alum in the bucket. Lab results show a minimum of 120 seconds of swirling is necessary for proper coagulation. CONAPAC instructed 60 passes of the coagulant during the installation of the POU system and it was found that many households are only swirling the coagulant for 30 seconds.

Covering of the 3rd bucket

In order to safely contain and store the treated water in the third bucket, the lid to the third bucket needs to remain on the bucket at all times, including during filtration. The current setup requires that the lid for the third bucket be either off entirely or open at one end to accommodate the filter when it's in use. Future POU systems should include longer tubing in order to allow the water to enter the third bucket from the side of the bucket through a small hole.

Explicit User Responsibilities

An important observation was disconnect between what users view as their responsibilities and what CONAPAC views as their role. Establishing guidelines and communicating user responsibilities would improve the resilience of the system. For example, if obtaining alum is the responsibility of households, it is important to communicate that upfront and perhaps provide household or communities with ideas regarding the best way that these resources can be obtained. If possible, helping communities organize community purchasing of alum may help reduce costs and ensure availability. This information should be provided in the user manual given to households.

Contact Information

CONAPAC's contact information should be printed on the instruction manual to inform households on how and when to contact the organization should the filter malfunction. CONAPAC will likely be the only source of technical assistance in the event that filters malfunction, so routine communication with communities and a clear protocol for approaching CONAPAC when this occurs will be necessary to ensure the long term use of these systems and community trust in CONAPAC. It should be noted that the visit to the communities was conducted three months after the distribution of the POU system therefore it remains unknown how the filter will perform over time and how much support will be needed from CONAPAC to ensure the long term sustainability of these systems over time.

Sources

John Adams, J. B. (2009). *Water, Sanitation and Hygiene Standards for Schools in Low-cost Settings.* Geneva: World Health Organization.

“Sawyer Filter Technology”. *Sawyer Saves*, 2013. Website, 18 September 2013. http://www.sawyer.com/sawyersaves/filter-tech.html

"What can I expect as my flow rate from my PointONE Filter™". *Sawyer Saves*, 2013. PDF, 18 September 2013. http://www.sawyer.com/sawyersaves/documents/flow-full.pdf

"'Sawyer Saves' Offers Hope to 900 Million People with no Access to Clean Water". *PRWeb,* 19 March 2012. Online Article, 18 September 2013. http://www.prweb.com/releases/2012/3/prweb9288501.htm

"3M™ Petrifilm™ E.Coli/Coliform Count Plates". *3M,* 2013. Website, 18 September 2013. http://solutions.3m.com/wps/portal/3M/en_US/Microbiology/FoodSafety/product-information/product-catalog/?PC_7_RJH9U523003DC023S7P92O3O87000000_nid=C0WJ62882Vbe29BDXSBJ7Fgl

Appendix – Survey questions

Survey Number:_____

SURVEY FOR FAMILIES WITH POU SYSTEM

SECTION 1: GENERAL INFORMATION

Do not read

Code	Question	Write
GI001	Date of Interview	*(day/month/year)*
GI002	Time interview started	(*24 hours)*
GI003	Interviewer	
GI004	District	
GI005	Community	
GI006	Distance (in minutes) from household to school (estimated by interviewer)	
GI006d	GPS Waypoint	

START SURVEY: read paragraph

Hello, my name is _____ and I am working with the University of Colorado in the United States and the National University of the Peruvian Amazon. We are doing a study on water in your community. The interview will last approximately 30 minutes. Your participation is voluntary. You may choose not to answer any of the questions or elect to stop the survey at any time, and your answers will be completely confidential and anonymous. We are not affiliated with an NGO or the government. We are students. Are you over 18 years old, and willing to participate in this survey?

GI009	Consent granted and over 18 years old	(1) Yes (2) Under 18 (3) No Consent

If "no," thank the interviewee and go to the next house.
If "yes," thank the interviewee, and mark "consent granted" on survey.
[Local contact in Iquitos: Profesora Giorly Machuca from UNAP (yanuagiomaes-7@hotmail.com, telephone number: 965605211).
Principal Investigator: Karl Linden, at karl.linden@colorado.edu or (01) 303-492-4798]

SECTION 2: QUESTIONS FOR ALL INTERVIEWEES: WATER USAGE

OB014	Are you the head of household?	(1) Yes (2) No (101) DK; (102) NR
In a normal week, how many times do you collect ***drinking water*** from…		
WU002b	The River	_____ times per week (102) DK; (102) NR

WU003b	A well	_____ times per week (101) DK; (102) NR
WU004b	Rainwater	_____ times per week (100)Every time it rains (100) DK; (102) NR
WU010	***(Skip this question if "0" for WU002b-WU005b and skip to SECTION 3)*** When you obtain water from _____(***read most frequent source***), do you treat it prior to consumption?	(1) Yes (2) No (3) Sometimes (101) DK (102) NR
WU015a	How do you treat it?	(1) Alum (2) DIGESA system (3) Chlorine (4) Point of use Filter (5) Other: (101) DK (102) NR

SECTION 3: QUESTIONS FOR ALL INTERVIEWEES: POINT OF USE FILTERS

POU01	Do you have a POU for filtering water? ***Yes: Skip to POU05***	1 Yes 2 No (101) DK (102) NR
POU02	We have heard that an organization named CONAPAC has distributed point of use filters for filtering drinking water in this community. Has this family received a POU filter? ***Yes: Skip to POU04***	1 Yes 2 No (101) DK (102) NR
POU03	Other families have received a POU filter. Why do you believe you did not? ***Skip to SECTION 4***	*Write reason:* (101) DK (102) NR
POU04	What happened to the POU filter? ***Skip to SECTION 4***	*Write:* (101) DK (102) NR
POU05	May we see it? ***In answer is no, skip to POU07***	1 Yes 2 No (101) DK (102) NR
POU06	May we take some water samples from the system? ***If permission to sample is granted, take sample from downstream side of the POU filter, then continue with the survey. If permission is not granted, continue with the survey.***	1 Yes 2 No (101) DK (102) NR
POU07	What is the filter number on the POU? (***If number is unknown, check buckets for number***)	Write number: _____ (101) DK (102) NR
POU08	During which month did you receive the POU filter?	Circle: (1) February (2) March (3) April (4) May (5) June (6) July (101) DK (102) NR
POU09	Is the POU filter working?	1Yes

	If answer is yes, skip to POU12	2 No 3 Other (write): (101) DK (102) NR
POU10	Why is it not working?	*Write:* (101) DK (102) NR
POU11	Have you attempted to repair the POU filter? ***Skip to POU13***	1 Yes 2 No (101) DK (102) NR
POU12	Have you had to fix the POU filter? ***If yes, skip to POU15***	1 Yes 2 No (101) DK (102) NR
POU13	What would you do if the POU filter stopped functioning?	*Write:* (101) DK (102) NR
OB015	***OBSERVATION*** ***For interviewer to annotate (do not ask):*** ¿How would you describe the condition of the system?	1 Almost perfect or perfect 2 Good 3 Bad 4 Not being used (101) DK (102) NR
OB015a OB015b OB015c	***For interviewer to annotate (not a question):*** Are there problems with the system such as:	Leaks: (1) Yes (2) No Lid missing on third bucket: (1) Yes (2) No Tap on third bucket not functioning: (1)Yes (2) No
POU15	Do you have alum?	1 Yes 2 No (101) DK (102) NR
POU16	Do you have a syringe?	1 Yes 2 No (101) DK (102) NR

Now we have some questions about the POU system when it is working.

POU17	How many times a week do you (or did you) filter water with the POU system??	_____ times per _____ [day/week] (101) DK (102) NR
POU18	Do you think that it is (or was) _____ to use the POU filter? ***(read the responses)***	1 Very easy 2 Easy 3 Not easy 4 Difficult (101) DK (102) NR
POU19	***(If POU filter is not functioning, skip this question)*** Does the POU filter always work? ***If yes, skip to a POU21***	1 Yes 2 Sometimes 3 No (101) DK (102) NR
POU20	Could you explain when it does not work and why?	_____ _____ _____ _____ _____ _____ ___

		(write answer)
POU21	How many times do you swirl the alum crystal in the first bucket?	_____ swirls (101) DK (102) NR
POU22	How many minutes do you allow the water to settle in the first bucket?	_____ minutes (101) DK (102) NR
POU23	Do you have to clean the POU filter sometimes? ***If answer is NO: Skip to POU26***	1 Yes 2 No 3 Other (write): (101) DK (102) NR
POU24	How many buckets of water do you filter before you have to clean the filter?	1 One bucket 2 Two buckets 3 Three buckets 4 Other (write): (101) DK (102) NR
POU25	How many syringes of water do you run through the filter when cleaning it?	_____ syringes (101) DK (102) NR
POU26	How fast does the water flow out of the filter? ***Read responses***	1 Fast 2 Slow 3 Very slow 4 Other: _____ (***write)*** (101) DK (102) NR
POU27	If after six months, CONAPAC offered to sell you the POU filter for 50 soles, would to purchase it?	1 Yes 2 No 3 Maybe (101) DK (102) NR
POU28	If CONAPAC gave you the opportunity to buy the system in payments, would you change your answer to the previous question?	1 Yes 2 No 3 Maybe (101) DK (102) NR
POU29	How much would you be willing to pay per month?	_____per month

SECTION 4: QUESTIONS FOR ALL INTERVIEWEES: COMMUNITY COHESION

CC002	How often are community meetings held?	_____times per month (101) DK (102) NR
CC003	When community meetings are held, you or someone from your households attends: ***(Read responses)***	(1) Always (2) Almost always (3) Half the time (4) Almost never (5) Never (101) DK (102) NR
CC01	Of all of the families in the community, how many would you say you're able to talk with about about private matters?	_____persons 101) Does not Know 102) No response
CC03	How many people in this community give their time or money to facilitate community development, for example to repair a path or work on a community project? ***(Read responses)***	1 Everyone 2 More than half 3 One half 4 Less than one half 5 Nobody 101) Does not Know 102) No response
CC04	In a typical month, approximately how many times do you help your community or neighbors, for example in a community project or in any other manner?	____ times (101) DK (102) NR

IE015	Have you ever asked a question at a community meeting?	(1) Yes (2) No (101) DK (102) NR
IE016b	How often are the POU filters discussed at community meetings? ***(Read responses)***	(1) Never (2) Almost never (3) Half the time (4) Almost always (5) Every meeting (101) DK (102) NR

SECTION 5: QUESTIONS FOR ALL INTERVIEWEES: KNOWLEDGE AND PROBLEMS

C001	Were there problems pertaining to the POU filters in the community, or problems pertaining to water in general? ***If no response, skip to section XX***	(1) Yes (2) No (101) DK (102) NR
C002	Why did these problems occur?	*Write:*
C003	How were these problems resolved?	*Write:*

Now we have some questions about the plant project.

SECTION 6: QUESTIONS FOR ALL INTERVIEWEES: ABOUT THE PROVIDER

II008	In the last year, how many times has your community had contact with CONAPAC?	_____times (101) DK (102) NR
SM005d	Do you believe the POU filter belongs to your family, the community, or CONAPAC? ***Do NOT read responses***	(1) Your family (2) CONAPAC (3) Community (4) Both (5) Other: (101) DK (102) NR
SAT02	How satisfied are you with the POU system?	(1) Very satisfied (2) Satisfied (3) Dissatisfied (101) DK (102) NR
SAT03	Before receiving the POU filter, did you used to treat your drinking water? ***If no, skip to SAT05***	(1) Yes (2) No (3) Sometimes (101) DK (102) NR
SAT04	What did you treat it with?	(1) Alum (2) Chlorine (3) POU filter (4) Other: (101) DK (102) NR
SAT05	Do you prefer to drink water the way you used to before receiving the POU filter, or do you prefer using the POU filter?	(1) Drink water the way we used to (2) Use the POU filter (3) (101) DK (102) NR

SECCIÓN 7: JAMI'S

JN001	Would you say the current quality of life in this community is better, the same, or worse than it was three years ago?	1) Better 2) Same 3) Worse 101) Does not Know 102) No Response
JN002	Do you believe the quality of life in this community will be better, the same, or worse three years from now?	1) Better 2) Same 3) Worse 101) Does not Know 102) No Response
JN003_2	Would you say the services provided to this community by the municipality are: ***(Read choices)***	1) Very good 2) Good 3) Not good or bad 4) Bad 5) Very bad 101) Does not Know 102) No Response
JN004	How interested do you believe the local government is in your community's problems? ***(Read responses)***	1) Very interested 2) Somewhat interested 3) Not very interested 4) Not interested 101) Does not Know 102) No Response
JN005_4	Can you name your district mayor?	*Write:* 102) No Response
JN006_5	How long is a mayor's term?	*(4* years*)* 1) Correct 102) No Response 2) Incorrect
JN007_6	What is the name of the process used to remove a mayor from office?	*(revocatoria)* 1) Correct 102) No Response 2) Incorrect
JN008_7	How long is a presidential term in Peru?	*(5* years*)* 1) Correct 102) No Response 2) Incorrect
JN009	On a different note, sometimes people and communities have problems they can't resolve themselves. Have you ever requested help or aid from the local authorities such as the mayor or municipality in order to resolve problems?	1) Yes 101) Does now Know 2) No 102) No Response
JN010_11b	Have you attended a government meeting or spoken with a civil servant in the last 5 years?	1) Yes 101) Does not Know 2) No 102) No Response
JN011	Of the following two statements, which one would you say applies most to you: It is the government's responsibility to provide your family with services. Or It doesn't matter who provides your family with services, as long as they're provided.	1) It is the government's responsibility to provide my family with services 2) It doesn't matter who provides my family with services, as long as they're provided. 101) Does not Know 102) No Response

Now I have some questions about organizations that are not from the government, who work with social matters such as education or nutrition. Examples of these organizations are Punchiwarmi, UNICEF, Operación Bendicion, o Cruz Roja.

JN012_12	Are there organizations or groups that have worked with your community or someone in your community in the last 5 years? *If no, skip to JN020*	1)Yes 2) No 101) Does not Know 102) No response
JN013	Can you name these organizations or groups? ***Ask if there are more and write their names*** ***If they say that they don't remember the names, mark this and continue*** ***If there are none, skip*** *JN020* *For coding JN013: could name/couldn't name/no NGOs/NS/NR. Then JN013a-JN013e for names.*	1. Name: 2. Name: 3. Name: 4. Name: 5. Name: 90. Does not remember names, but there have been some 0. No organizations 101) Does not Know 102) No Response
JN014	What project or service did _____ provide? *[state name of first organization or group]*	*Write:*
JN015	Would you say the results of this service or project were: ***(Read choices)***	1) Very good 2) Good 3) Not good or bad 4) Very bad 5) Very bad 6) The organization did not complete the project 101) Does not Know 102) No Response
JN016	*If more than one organization could not be named, or did not recall, skip to JN018.* What project or service did _____ provide? *[state name of first organization or group]*	*Write:*
JN017	Would you say the results of this service or project were: ***(Read choices)***	1) Very good 2) Good 3) Not good or bad 4) Bad 5) Very bad 6) The organization did not complete the project 101) Does not Know 102) No Response
JN018	Keeping in mind the organizations that have visited this community, have you or someone in your family received goods or services from these organizations or groups?	1) Yes 101) Does not Know 2) No 102) No Response
JN019	In the last two years, how many times have you or someone in your family attended a meeting or spoken with these organizations?	_____times 101) Does not Know 102) No Response
JN020	In general, how interested do you believe non-governmental organizations are in problems in	1) Very interested 2) Somewhat interested

	communities like this one?	3) Not very interested 4) Not interested 101) Does not Know 102) No Response
JN021	Who do you trust more to complete projects that will better your community? ***(Read choices)***	1) NGOs, like organizations or groups 2) The government 3) Both the same 4) Neither 101) Does not Know 102) No Response

SECTION 8: PERSONAL INFORMATION

Now to wrap things up, I have some statistical questions.

DG001	What is your age?	____ DK/NR = 0
CC010	How many months or years have you lived in this community?	_____years_____months DK /NR = 0
CC009	How likely is in that you will live in this community in three years? ***(read choices)***	(1) Very likely (2) Somewhat likely (3) Not very likely (4) Not possible (101) DK (102) NR
Does your home have…		
DG002b	A generator	(1) Yes (2) No (101) DK (102) NR
DG002c	Solar power	(1) Yes (2) No (101) DK (102) NR
DG002	A radio	(2) Yes (2) No (101) DK (102) NR
DG003	A television	(1) Yes (2) No (101) DK (102) NR
DG004	Boat with a motor	(1) Yes (2) No (101) DK (102) NR
DG005	***(Skip if they do not have electricity, but mark answer)*** A refrigerator	(1) Yes (2) No (101) DK (102) NR
DG006	A cellular pone (or house phone)	(1) Yes (2) No (101) DK (102) NR
DG007b_a DG007b_b DG007b_c DG007b_d DG007b_e	How many of these animals do you own? ***(Read choices)***	Cows: _____ Pigs: _____ Goats: _____ Chickens: _____ Other:_____
DG010	How many people live in this house?	_____ (101) DK (102) NR
DG011	How many people under the age of 5 live in this	_____

	house?	(101) DK (102) NR

DG012: What is the highest level of education you completed?

	1st	2nd	3rd	4th	5th	6th	
None	0						
Elementary	1	2	3	4	5	6	
Secondary	7	8	9	10	11		
College	12	13	14	15	16	17	18+
DK =101/NR=102							

DG012b: Of everyone living in your house, what is the highest level of education completed by the person with the highest level of education?

	1st	2nd	3rd	4th	5th	6th	
None	0						
Elementary	1	2	3	4	5	6	
Secondary	7	8	9	10	11		
College	12	13	14	15	16	17	18+
DK =101/NR=102							

We've reached the end of our survey. Thank you for taking the time to speak with us. Your participation in this survey is greatly appreciated. We wish you and your family the very best. Do you have any questions for us?

SECTION 9: INTERVIEWER OBSERVATIONS

OB016	Does it look like they are using the system?	1 Yes 2 Not sure, but it looks like they are 3 Not sure, but it looks like they aren't 4 No
OB007	How long did the interview take?	_____minutes
OB008	Gender of person being interviewed	(1) M (2) F
OB013	Was there anything special or different about the interview we need to know? (Problems, impressions, anything special, etc.)	